Appendix A:

Subroutine and Function Calls

within FEHM

Table 1.Subroutine and Function Calls within FEHMN

Routine	Description	Calls	Called by
main	Program main was added above fehmn so that all arrays would be allocated before being used (required for the IBM).	fehmn	
air_cp	Compute the heat capacity of air and the derivative with respect to temperature.		thrmwc
air_rdof	Reduce the two-degree-of-freedom solution to Richard's equation.	interblock_iso, thrair	airctr, gensl2
airctr	Manage the isothermal air-water calculations.	air_rdof, gensl2, thermw, thrair, *min0*	bnswer, input, startup, varchk, wrtout
allocmem	Allocate memory to dynamic variable arrays.	mmgetblk, storage_derivatives	fehmn
angle3	Determine the angles of rotation needed to point the z-axis from mass point 'i' to neighbor 'j'.	*sqrt*	eullag3
anonp	Categorize elements and call routines to generate finite-element coefficients.	determ, gencof, md_nodes, mmgetblk, mmrelblk, sx_combine, storage_derivatives, zeroi_out, *abs, iabs, max0, sqrt*	startup
area2d_tri	Calculate the total area of a triangle and the three Voronoi areas along each of the three sides.	*sqrt*	anonp, gncf3
avs_io	Produce FEHM output in AVS UCD or binary format.	avs_write_cord, avs_write_struc, c_close, file_prefix, namefile2, write_avs_node_con, write_avs_node_mat, write_avs_node_s, write_avs_node_v, write_avs_ucd_header, write_binary_geo, write_binary_header, write_binary_node_con, write_binary_node_mat	contr

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
avs_io (continued)		write_binary_node_s, write_binary_node_v	
avs_write_cord	Output AVS coordinate information for FEHM.		avs_io
avs_write_struc	Output AVS mesh-connectivity information for FEHM.	elem_type	avs_io
bcon	Manage boundary conditions.	*abs*	csolve, fehmn, startup
binghm	Calculate pressure drop for Bingham fluid.	cubic, *asin, sin, sqrt*	permp
bit	Set specified bit to the input state.	*and*, *iand, ishft*	geneq1, geneq2, geneqc
bnswer	Call routines to assemble finite-element equations and solve for the Newton-Raphson equations.	aircrtr, dpdp, gensl1, gensl3, gensl4, outbnd, varchk, *abs*	fehmn, steady
c_close	C routine to close AVS binary format output file.	*close*	avs_io
c_open	C routine to open AVS binary format output file.	*creat*	namefile2
cappr	Calculate capillary-pressure functions.	initdata, null	thermw, thrair, thrmwc
casson	Calculate equivalent Darcy permeability for a Casson fluid.	cubic, fourth, *sqrt*	permp
cell_time	Compute fluid residence time for cell and calculate probability of a particle moving to a neighbor node.		part_track
check_sx	Check volumes and finite-element flow coefficients.	*max*	datchk
close_files	Close all open files.		termio
cnswer	Call routine to generate tracer transport equations and call tracer equation-of-state routines.	coneq1, dualta, gencon, gentdp, react, thermc, zeror_out, *abs, max*	csolve
cntlin	Read I/O file names from control file, set unit numbers, and open files.	null, setunits	cntlio
cntlio	Manage the opening and closing of files using control file input.	cntlin, writeio	iofile, termio

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
co2ctr	Provide overall control for an isothermal air-water simulation.	humidity, initdata, psatl, *abs, exit*	fehmn, input, startup, timcrl, wrtout
coeffc	Change coefficients of polynomial fits of the thermodynamic properties specified.		startup
concadiff	Compute diffusion coefficient based on volumetric water content.		coneq1, csolve, rdcon
concen	Provide overall control for a tracer simulation.	contrc, csolve, diskc, diskp, plotc1, part_track, rdcon, wrtcon, wrtptrk	contr, contrj, disk, fehmn, input, startup, wrtout
coneq1	Generate the equations of tracer transport.	*abs, max, sqrt*	cnswer, gentdp
coneq1mdnode	Compute the Jacobian and residual terms of the concentration equation associated with multiply defined node connections.		cnswer, gentdp
contr	Write out data for contour plots at specified times.	avs_io, concen, contrj, veloc, *max*	fehmn, startup, timcrl
contrc	Write out tracer data for contour plots.		concen
contrj	Write to contour plot tape using PATRAN format.	concen, veloc	contr
crdpdp	Update solution for double-porosity/double-permeability problem.		dpdp
csolve	Organize tracer solution so smaller time steps can be used for the tracer solution than for the flow solution.	bcon, cnswer, node_rxn, plotc1, resettrc, solstore, tyming, wrtcon, *abs, dlog10, exp, max, min*	concen
ctdpdp	Update concentrations for double-porosity/double-permeability solution.		dpdp
cubic	Solve cubic equation.	*abs, sqrt*	binghm, casson
data	Initialize scalar variables, zero all arrays, and load thermodynamic coefficients.	zeroi_out, zeror_out	fehmn

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
datchk	Initial value analysis and data check.	check_sx, min_max, *abs, max, min*	fehmn
dated	Determine the current date and time.	*dateh* (cray), *idate, itime, mod* (hp, sun), *fdate_* (ibm)	disk, fehmn
daycrl	Compute new time-step size using adjusted time-step multiplier if necessary.	*log10*	timcrl
determ	Evaluate determinates.		anonp
diagnostics	Print out worst residuals.	*abs*	fehmn
disk	Read and/or write files for restart purposes.	concen, dated, stress, *max*	fehmn, startup, timcrl
diskc	Read and/or write restart files for tracer variables.		concen
diskp	Read and/or write restart files for particle-tracking variables.		concen
done_macro	Close optional input file.		input, scanin
dpdp	Provide overall control for a dual-porosity/dual-permeability solution.	crdpdp, ctdpdp, gensdp, gensdp3, indpdp, rddpdp, varchk	bnswer, gensdp, gensdp3, input, startup
dpdp3	Load dual-porosity/dual-permeability solution into solution matrix for three-degree-of-freedom system (air, water, heat).	*max*	gensdp3
dpdpfa	Load dual-porosity/dual-permeability solution into solution matrix for an isothermal air-water simulation.	*max*	gensdp
dpdpfh	Load dual-porosity/dual-permeability solution into solution matrix for a heat, water, water vapor simulation.	*max*	gensdp
dpdpta	Load dual-porosity/dual-permeability solution into solution matrix for tracer simulation.	*abs, max*	gentdp
drill	Regulate simulated drilling rate.	*max*	welbor

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
dual	Provide overall control for a dual-porosity solution.	dualex, dualfa, dualfh, dualtx, initdata, varchk, *max*	fehmn, gencon, gensl1, gensl2, gensl4, input, startup, timcrl
dualex	Extract dual-porosity solution from primary-variable solution.		dual
dualfa	Compute the Jacobian and residual terms of the mass-balance equations at each node for a dual-porosity isothermal air-water solution.	varchk, *max*	dual
dualfh	Compute the Jacobian and residual terms of the heat and mass equations at each node for a dual-porosity solution.	varchk, *max*	dual
dualta	Compute the Jacobian and residual terms of the concentration equation at each node for a dual-porosity solution.	*abs, max*	cnswer
dualtx	Back substitute to get tracer solution for dual-porosity nodes.		dual
dvacalc	Evaluate air/water-vapor diffusion coefficients.		thrmwc
elem_type	Determine element type.		avs_write_struc
elem_type_binary	C routine to determine element type.		write_binary_geo
enthp	Calculate enthalpy at a node as a function of temperature and pressure.		fehmn, steady, welbor
eullag3	Convert between two geometric reference frames: given a point i, a nearest neighbor j, and a vector, rotate the vector from x,y,z space to a,b,c space.	angle3	rotate
fehmn	Primary controlling routine for finite-element heat and mass transfer in porous media.	tyming, dated, iofile, setparams, allocmem, data, infiles, startup, datchk, timcrl, user, welbor, enthp, bnswer, resetv, varchk, dual, diagnostics, fimpf, bcon, co2ctr	main

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
fehmn (continued)		sice, veloc, concen, wrtout, plot, contr, disk, *abs, max, mod*	
file_prefix	Determine prefix of input file name.		avs_io, termin
film	Regulate film coefficient.	htcchg, *abs, max, sqrt*	welbor
fimpf	Calculate fraction of variables over a given tolerance.	*abs*	fehmn
flxo	Calculate internode fluxes.	near3, *abs, max, sqrt*	input, wrtout
fourth	Solve fourth-order equation.	*abs, sqrt*	casson
fprop	Change fluid properties in wellbore and annulus.		welbor
freef	C routine to free allocated memory.	*free*	mmrelblk
gencof	Call routines to generate finite-element coefficients, perform the numerical integration of the elements.	gncf2, gncf3, mmgetblk, mmrelblk, zeror_out	anonp
gencon	Call routines to generate tracer equations and call solver to obtain Newton-Raphson equations for tracer variables.	dual, mmgetblk, mmrelblk, rd1dof, solve_new, storage_derivatives, *max, min, sqrt*	cnswer
gendat	Generate coordinates and element information in simple geometric problems.		incoord
geneq1	Generate equations for Newton-Raphson corrections for water/vapor flow without noncondensible gas.	bit, setbit	gensdp, gensdp3, gensl1
geneq2	Generate equations for Newton-Raphson corrections for isothermal air-water solution.	bit, setbit	gensdp, gensl2
geneq3	Generate equations for Newton-Raphson corrections for heat conduction only (i.e., permeability).		gensdp, gensdp3, gensl2, gensl3
geneqc	Generate equations for Newton-Raphson corrections for water and noncondensible gas flow.	bit, psat, setbit, zeolites	gensdp3, gensl4

Table 1.Subroutine and Function Calls within FEHMN (Continued)			
Routine	**Description**	**Calls**	**Called by**
geneqmdnode	Generate equations to multiply defined nodes.	bit, setbit	mdnodes
gensdp	Solve isothermal air-water equations with full Jacobian (unsymmetrical, 2n by 2n).	dpdp, dpdpfa, dpdpfh, geneq1, geneq2, geneq3, mmgetblk, mmrelblk, nrmlz4, rdof_new, solve_new, storage_derivatives, switch, switchb, *abs, max, min, sqrt*	dpdp
gensdp3	Solve nonisothermal air-water equations with full Jacobian (unsymmetrical, 3n by 3n).	dpdp, dpdp3, geneq1, geneq3, geneqc, mmgetblk, mmrelblk, normal_dof, rdof_new, solve_new, storage_derivatives, switch, switchb, *abs, max, min, sqrt*	dpdp
gensl1	Call routines to generate the Newton-Raphson equations for water-only problems and call equation-solver subroutine to solve the heat- and mass-transfer equations with full Jacobian (unsymmetric, 2n by 2n).	dual, geneq1, mmgetblk, mmrelblk, normal, rdof_new, solve_new, storage_derivatives, switch, switchb, *abs, max, min, sqrt*	bnswer
gensl2	Call routines to generate the Newton-Raphson equations for isothermal air-water and call equation-solver subroutine to solve with full Jacobian.	air_rdof, dual, geneq2, geneq3, mmgetblk, mmrelblk, normal, rdof_new, solve_new, storage_derivatives, switch, switchb, *abs, max, min, sqrt*	airctr
gensl3	Call routines to generate the Newton-Raphson equations for heat conduction only and call equation-solver subroutine.	geneq3, mmgetblk, mmrelblk, rd1dof, solve_new, storage_derivatives, *abs, max, min, sqrt*	bnswer
gensl4	Call routines to generate equations for water/noncondensible-gas problems and call equation-solver subroutine to solve the heat and mass equations with noncondensible gas (full Jacobian, unsymmetric 3n by 3n).	dual, geneqc, mmgetblk, mmrelblk, normal, rdof_new, solve_new, storage_derivatives, switch, switchb, *abs, max, min, sqrt*	bnswer

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
gentdp	Solve tracer equations with full Jacobian (unsymmetrical, 2n by 2n).	coneq1, dpdpta, mmgetblk, mmrelblk, normal, rdof_new, solve_new, storage_derivatives, thermc, *max, min, sqrt*	cnswer
getconc	Interpolate between background levels of input concentration for use with the particle tracking.		part_track
geoin	Read element and coordinate information from preprocessor with alternate format.	inmentat, inpatran	incoord
gncf2	Generate 2-D finite-element coefficients.	pebi, shap2r	gencof
gncf3	Generate 3-D finite-element coefficients.	lubksb0, ludcmp0, pebi3, shap3p, shap3r	gencof
heatb	Modify energy source to account for heat generation at the drill bit.	qhuser, *abs*	permp, welbor
htcchg	Change the fouling coefficients of drill pipe and casing as function of time and depth.		film
humidity	Calculate the saturation for a given humidity value.	*log*	co2ctr
incond	Read thermal-conductivity data.	initdata, *max*	input
incoord	Control reading of input coordinate data.	gendat, geoin, null, *iabs*	infiles
inctrl	Read control variables.	initdata, *abs min0*	input
indpdp	Modify fracture volume at nodes for dpdp calculations.		dpdp
infiles	Control reading of input data files.	incoord, input, rarng, writeio, zone	fehmn
inflo2	Read flow data input by planes for 3-D models.	null, *abs, max0*	input
inflow	Read flow data.	initdata, mmgetblk, mmrelblk, *abs*	input
inhflx	Read heat-flux data.	initdata	input

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
initdata	Read in an arbitrary number of lines of data and set parameter values at given nodes.	mmgetblk, mmrelblk, null, zeroi_out, *abs*, *nint*	co2ctr, dual, incond, inctrl, inflow, inhflx, inperm, inpres, inptrk, inrock, inzeol, porosi, rdcon, rddpdp, rdthick, renum, rlperm, sice, vcon
inmentat	Read in geometric data generated by mentat mesh generator.		geoin
innode	Read/find node numbers for output.	near3, null, *abs*	input
inpatran	Read in geometric data generated by patran mesh generator.		geoin
inperm	Read permeability data.	initdata, *max*	input
inpres	Read nonuniform pressure and temperature or saturation data.	initdata, mmgetblk, mmrelblk, psat, *abs*	input
inptrk	Read particle-tracking data.	initdata, null	input
input	Control reading of input data file.	airctr, co2ctr, concen, done_macro, dpdp, dual, flxo, incond, inctrl, inflo2, inflow, inhflx, innode, inperm, inpres, inptrk, inrock, intime, inzeol, md_nodes, null, parse_string, porosi, read_avs_io, read_rxn, renum, rlperm, sice, start_macro, sther, stress, thickness, user, vcon, welbor, zone, *abs*	infiles
inrock	Read rock-property data.	initdata	input
interblock_iso	Generate interblock flow for air-water equations.		air_rdof
intime	Read time-step input.	null	input
inverf	Calculate the inverse of the error function for a value of x between 0 and 1.	*alog10*	time_diff

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
inzeol	Read zeolite-hydration data.	initdata, psat, zeolites, zeror_out	input
iofile	Manage the opening of input and output files.	cntlio, termio	fehmn
lubksb	Perform forward and back substitution for N-degree-of-freedom matrix elements.		node_rxn
lubksb0	Perform forward and back substitution for N-degree-of-freedom matrix elements.		gncf3, normal_dof, pebi3
ludcmp	Perform Gauss elimination on N-degree-of-freedom matrix elements.	*abs*	node_rxn
ludcmp0	Perform Gauss elimination on N-degree-of-freedom matrix elements.	*abs*	gncf3, normal_dof, pebi3
mallocf	C routine to allocate memory.	*exit, malloc, printf*	mmgetblk
md_nodes	Manage multiply defined nodes.	mmgetblk	anonp, input, startup
min_max	Find the minimum and maximum parameter values and their location.		datchk
mmgetblk	Allocate memory to an array.	mallocf	allocmem, anonp, gencof, gencon, gensdp, gensdp3, gensl1, gensl2, gensl3, gensl4, gentdp, inflow, initdata, inpres, md_nodes, set_ptrk, split, startup, storage_derivatives, storsx, thermw, thickness, zone
mmrelblk	Deallocate array memory.	freef	anonp, gencof, gencon, gensdp, gensdp3, gensl1, gensl2, gensl3, gensl4, gentdp, inflow, initdata, inpres, split, startup, thermw, storage_derivatives, storsx, thickness, zone

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
mod_eqs_ngas	Modify equations if no gas is present.	*abs*	gensl4
mult_rxn	Compute the reaction-rate terms for each reaction for the given species and node point.	rxn_product, *abs, dlog10, exp, max, min*	node_rxn, react
namefile2	Generate name for AVS format output file.	c_open	avs_io
near3	Find nearest node to a set of coordinates (x, y, z).	*sqrt*	flxo, innode, zone
nearn	Determine the nearest node (n) to a given set of coordinates (x, y).	*sqrt*	welbor
newton	Calculate pressure drop for Newtonian fluid.	*log, log10*	permp
node_rxn	Compute the updated concentrations of all species at a given node after constructing an *nspeci* x *nspeci* matrix that includes coupling of the concentrations.	lubksb, ludcmp, mult_rxn	csolve
normal	Normalize Newton-Raphson equations and calculate sum-squared sum of residuals.		gensl1, gensl2, gensl4, gentdp
normal_dof	Normalize equations for coupled problems.	lubksb0, ludcmp0	gensdp3
nrmlz4	Normalize the matrix equations.	*abs, max*	gensdp
null	Check for null lines or all 0's in lines.	*char, len*	cntlin, incoord, inflo2, initdata, innode, inptrk, input, intime, rdcon, read_rxn, rlperm, scanin, vcon, zone
outbnd	Test the dependent variables to determine if they are within the bounds set by the thermodynamic properties.		bnswer
parse_string	C routine to parse input line with character, integer, and real input.		input, rdcon, read_rxn
part_track	Control particle-tracking simulation.	cell_time, getconc, ran_sp, set_ptrk, time_diff, time_disp, *abs, dble, exp, max, mod, real, sqrt*	concen

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
pebi	Calculate internodal area using perpendicular bisectors (2-D).	*mod, sqrt*	gncf2
pebi3	Calculate internodal volume using perpendicular bisectors (3-D).	ludcmp0, lubksb0, *abs*	gncf3
peint	Set up initial temperature gradients where gradient information is user specified.	*abs, max*	startup
permp	Calculate equivalent Darcy permeability for pipe flow.	binghm, casson, heatb, newton, power, *abs, max*	welbor
plot	Write out data for time-history plots at particular nodes.		fehmn, startup, timcrl
plotc1	Write out tracer data for time-history plots. Print out at flow time steps.		concen, csolve, rdcon, set_ptrk
porosi	Read in data for pressure-dependent porosity and permeability models and calculate porosity and permeability functions.	initdata, welbor, *iabs*	input, startup, thermw, thrair, wrtout
power	Calculate equivalent permeability for power-law fluid.	*log, log10*	permp
psat	Calculate the saturation pressure of water for a given temperature.	*abs*	geneqc, inpres, inzeol, thermw
psatl	Calculate the saturation temperature or pressure.	vaporl, *abs*	co2ctr, thrmwc, varchk
qhuser	User-specified dissipation rate.		heatb
radius	Modify finite-element coefficients to obtain a radial model.	*min, max*	startup
ran_sp	Generate a pseudorandom number with a uniform distribution between 0 and 1.	*mod, real*	part_track, time_diff
rarng	Rearrange 3-D coordinates to obtain 2-D problems when enabled.		infiles
rd1dof	Solve the equations generated for heat conduction by a reduced degree-of-freedom method.	solve, *sqrt*	gencon, gensl3

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Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
rdcon	Read in tracer data and initialize tracer variables.	initdata, null, parse_string, plotc1, thermc, userc, *abs, dlog10, exit, exp, max, min*	concen
rddpdp	Read the input data for a dpdp solution.	initdata	dpdp
rdof_new	Reduce a 3n*3n matrix into a 2n*2n matrix or an n*n matrix using the RDOF or IRDOF algorithms.	solve_new	gensdp, gensdp3, gensl1, gensl2, gensl4, gentdp
rdthick	Read input data for variable thickness.	initdata	thickness
react	Compute the reaction terms and add to the Jacobian and the residual for each node.	mult_rxn, *abs, max*	cnswer
read_avs_io	Read input file and set io flags.		input
read_rxn	Read the data for multiple, interacting solutes.	null, parse_string, setup_rxn, *abs*	input
read_sx	Read finite-element coefficients.		storsx
renum	Read node-renumbering data.	initdata	input
resettrc	Reduce time step of the solute-transport calculation and reset the values of all parameters before reinitiating the calculation.		csolve
resetv	Reset the dependent variables to the last time step value. Used when iteration limits are exceeded and a particular time step is restarted.		fehmn
rlperm	Calculate relative-permeability functions for vapor and liquid.	null, initdata, vgcap, vgcap_fit, vgrlp, welbor, *max*	input, thermw, thrair, thrmwc
rock	Regulate rock properties.	*max0*	welbor
rotate	Initiate 3-D matrix rotation.	eullag3	coneq1, csolve
rxn_product	Compute the reaction-rate terms for each reaction for the given species and node point.	*max*	mult_rxn
scanin	Scan input file for parameters needed prior to data input.	done_macro, null, start_macro, *max*	setparams

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
set_ptrk	Set up starting nodes and times for particle tracking.	mmgetblk, plotc1, *abs, int*	part_track
setbit	Set specified bit to the input state.	*and, iand, ior, ishft, not, or*	geneq1, geneq2, geneqc
setord	Set up the order of solution for the equations at each node.		startup
setparams	Initialize/set parameter values.	scanin, *max*	fehmn
setunits	Set file unit numbers.		cntlin, termin
setup_rxn	Set up arrays identifying the location and type of a particular species in a reaction.		read_rxn
setzone	Enter properties using geometric zone description.	sfn2r, sfn3r, *abs, max, min, sqrt*	zone
sfn2r	Evaluate shape functions for 2-D calculations. (Interpolation routine used by **zone**.)		setzone
sfn3r	Evaluate shape functions for 3-D calculations. (Interpolation routine used by **zone**.)		setzone
shap2r	Evaluate 2-D finite-element shape functions at quadrature points.	*sqrt*	gncf2
shap3p	Evaluate 3-D prism-element shape functions at quadrature points.		gncf3
shap3r	Evaluate 3-D quadralateral-element shape functions at quadrature points.	*sqrt*	gncf3
sice	Read in data for simulation with ice present.	initdata, sther	fehmn, input, startup, wrtout
solstore	Compute the tracer mass storage and sorption terms of the residuals equations and their derivatives.	*abs, dlog10, exp, max*	csolve, thermc
solve	Solve the one-degree-of-freedom linear system of equations.	*abs, max, sqrt*	rd1dof
split	Split rectangles/bricks into triangles/tetrahedrals and average so grid orientation is not present.	mmgetblk, mmrelblk, *abs, min*	startup

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
start_macro	Allow input to be read from any file.		input, scanin
startup	Perform miscellaneous startup calculations.	airctr, anonp, bcon, co2ctr, coeffc, concen, contr, disk, dpdp, dual, md_nodes, mmgetblk, mmrelblk, peint, plot, porosi, radius, setord, sice, slvesu, split, storsx, steady, thickness, tyming, varchk, welbor, zeror_out, *abs, max, max0*	fehmn
steady	Set up initial pressure distribution when gravity is present (enabled).	bnswer, enthp, *abs*	startup
sther	Set thermodynamic parameters when simple thermodynamics are invoked.		input, sice
storage_derivatives	Allocate memory for derivative arrays and initialize values, or deallocate derivative arrays.	mmgetblk, mmrelblk, zeror_out	allocmem, anonp, gencon, genspd, genspd3, gensl1, gensl2, gensl3, gensl4, gentdp
storsx	Manage the storage or retrieval of element coefficients from auxiliary file.	mmgetblk, mmrelblk, read_sx	startup
stress	Blank routine that returns without doing anything (for compatibility with other versions of FEHM).		disk, input, wrtout
switch	Reorder the “a” matrix.		genspd, genspd3, gensl1, gensl2, gensl4
switchb	Reorder the “b” matrix.		genspd, genspd3, gensl1, gensl2, gensl4
sx_combine	Combine dimensions of a variable.		anonp
termin	Read I/O file names from terminal, set unit numbers, and open files.	file_prefix, setunits	termio
termio	Manage the opening and closing of files using terminal input.	close_files, cntlio, termin, writeio	iofile

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
thermc	Evaluate tracer equation-of-state information.	solstore, userc, *abs, dlog10, exp, max*	cnswer, gentdp, rdcon
thermw	Evaluate the thermodynamic properties (density, enthalpy, and viscosity) as a function of pressure and temperature (or saturation).	cappr, mmgetblk, mmrelblk, porosi, psat, rlperm, vfcal, welbor, *abs*	airctr, varchk
thickness	Modify volumes and finite-element coefficients to account for variable thickness.	mmgetblk, mmrelblk, rdthick	input, startup
thrair	Calculate coefficients and derivatives for isothermal air-water system.	cappr, porosi, rlperm	airctr, air_rdof
thrmwc	Evaluate the thermodynamic properties (density, enthalpy, and viscosity) as a function of pressure, temperature, and partial pressure of noncondensible gas for water/noncondensible-gas problems.	air_cp, cappr, dvacalc, psatl, rlperm, vfcal, *max*	varchk
timcrl	Control time-step information and stopping criteria.	co2ctr, contr, daycrl, disk, dual, plot, *abs*, *iabs*	fehmn
time_diff	Compute diffusion time for a particle.	inverf, ran_sp	part_track
time_disp2	Compute dispersion time for a particle.		part_track
tyming	Calculate CPU time for a particular computer run. Call is made to the system clock of the computer on which it is run.	*second* (cray), *secnds* (hp), *etime_* (ibm), *dble, etime* (sun)	csolve, fehmn, startup
user	A user-programmed subroutine that provides for changing common block variables every time step. Disabled (i.e., not certified as part of this baseline) for YMP project.		fehmn, input
userc	User-defined subroutine for changing common variables associated with tracer transport. Disabled (i.e., not certified as part of this baseline) for YMP project.		thermc, rdcon
vaporl	Calculate the vapor-pressure-lowering contribution to saturation pressure.	*exp*	psatl

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
varchk	Decide, based on current pressure, temperature, and saturation values, current phase state (fully saturated, partially saturated). Call routine THERMW or THRMWC to update thermodynamic properties of density, enthalpy, and viscosity. Add the Newton-Raphson corrections to the dependent variables.	aircrtr, psatl, thermw, thrmwc, vcon, *max, max0*	bnswer, dpdp, dual, dualfa, dualfh, fehmn, startup
vcon	Calculate variable thermal conductivity.	initdata, null, *sqrt*	input, varchk
veloc	Calculate fluid velocities in coordinate directions.	*abs, max, sqrt*	contr, contrj, fehmn
vfcal	Change porosity and permeability as functions of pressure.	*exp, log*	thermw, thrmwc
vgcap	Compute the capillary pressure and derivatives for the van Genuchten model.		rlperm
vgcap_fit	Provide linear or cubic fit to capillary pressure data.		rlperm
vgrlp	Compute the liquid relative permeability and derivative for the van Genuchten model.		rlperm
welbor	Do wellbore input and simulation.	drill, enthp, film, fprop, heatb, nearn, permp, rock, *abs, int, log, min*	fehmn, input, porosi, rlperm, startup, thermw
write_avs_node_con	Output AVS concentration fields from FEHM.	*min, max*	avs_io
write_avs_node_mat	Output AVS scalar-node information for FEHM mesh materials.	*float*	avs_io
write_avs_node_s	Output AVS scalar-node information for FEHM.		avs_io
write_avs_node_v	Output AVS vector-node information for FEHM.		avs_io
write_avs_ucd_header	Output AVS UCD header information.		avs_io
write_binary_geo	C routine to write AVS binary-coordinate and mesh-connectivity information for FEHM.	elem_type_binary, *lseek, write*	avs_io

Table 1.Subroutine and Function Calls within FEHMN (Continued)

Routine	Description	Calls	Called by
write_binary_header	C routine to write AVS binary UCD header information.	*write*	avs_io
write_binary_node_con	C routine to write AVS binary concentration fields from FEHM.	*lseek, printf, strcat, write*	avs_io
write_binary_node_mat	C routine to write AVS binary scalar-node information for FEHM mesh materials.	*lseek, printf, strcat, write*	avs_io
write_binary_node_s	C routine to write AVS binary scalar-node information for FEHM.	*lseek, printf, strcat, write*	avs_io
write_binary_node_v	C routine to write AVS binary vector-node information for FEHM.	*lseek, printf, strcat, write*	avs_io
writeio	Write assigned file names, unit numbers, and file purpose to specified output unit.		cntlio, infiles, termio
wrtcon	Write output for tracer at specified intervals.	*abs*	concen, csolve
wrtout	Write output information at a user-specified interval.	airctr, co2ctr, concen, flxo, porosi, sice, stress, *abs*, *dfloat*, *max0*	fehmn
wrtptrk	Output particle-concentration data.		concen
zeolites	Compute the energy/ water-source/sink terms due to a zeolite deyhydration reaction.	*dlog*	geneqc, inzeol
zeroi_out	Initialize integer array to zeros.		anonp, data, initdata
zeror_out	Initialize real array to zeros.		data, cnswer, gencof, inzeol, startup, storage_derivatives
zone	Divide the input problem space by allowing the user to define zones geometrically and then labeling the nodes as to which zone they belong to. These zones are then used to assign properties to the nodes.	mmgetblk, mmrelblk, near3, null, setzone	infiles, input

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Table 1.Subroutine and Function Calls within FEHMN (Continued)			
Routine	**Description**	**Calls**	**Called by**
slvesu and solve_new are reuse components from the GZSOLVE Application ECD-97:			
slvesu	Set up equation solver by identifying fill-in positions in the Newton-Raphson matrix.	N/A	startup
solve_new	Perform preconditioned conjugate gradient solution of a set of linear, algebraic equations.	N/A	gencon, genspd, gensl1, gensl2, gensl3, gensl4, gentdp